# Refinement and Development of Fire Management Decision Support Models Through Field Assessment of Relationships Between Stand Characteristics, Fire Behavior and Burn Severity

**Research proposal responds to U.S. Department of the Interior – U.S. Department of Agriculture Joint Fire Science 2004-2 AFP, Task Statement #1. Closing date: 15-December-2003.**

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**Duration of Project:** 2 years

**Abstract:**
The Alaska Interagency Fire Management Plan promulgates policy objectives that recognize the ecological importance of perpetuating natural fire regimes. The same policy also directs land managers to balance the protection of ecological principles with appropriate risk management to protect anthropogenic values susceptible to fire. Fire management in Alaska needs the ability to predict fire behavior and to understand successional trends of fuel characteristics in relation to flammability in order to achieve policy objectives. This research aims to improve these **two** knowledge gaps that exist in Alaska (AFP 2004-2 Task #1 with linkages to AFP-2004-1 Task #1). **The first objective of this research is to develop a flammability curve model for black spruce boreal forest types using currently available datasets of seral stage stand characteristics and appropriate fuel attributes followed by testing this curve with data collected from wildfire and prescribed fire events.** This process will serve land management agencies well in creating long-term natural resource management plans that balance ecological and social needs by providing a faster, reliable method of defining fuel hazards at a landscape scale. **The second objective of this research is to assess two black spruce fuel type fuel model inputs for decision support models widely used in Alaska through direct field measurements of fire behavior.** This objective will add an additional degree of confidence to the application of these models and any discrepancies between actual fire behavior and model predictions will be used to recommend specific changes to improve the model's application in the Alaskan black spruce boreal forest type. Data obtained from fire events are unique and will have broader potential applications for improving a host of forest simulation models used for boreal forests. This project will realize significant cost savings by merging data collection efforts with Roger Ottmar's current JFSP project (AFP 2003-2 Task #1). Products will be distributed through web page dissemination, published materials and workshops with Alaska fire and land managers.

## INTRODUCTION

### Project Justification

The value of wildland fire as an ecological linchpin maintaining the structure of the vast and complex boreal forest ecosystem has been publicly realized through the guiding principles of the statewide Alaska Interagency Fire Management Plan, policy that governs a majority of the Alaskan landscape. The same set of guiding principles directs land managers to balance the need to retain natural fire regimes with appropriate risk management to protect anthropogenic values susceptible to fire (AWCG 1998). The ecological value of fire in the boreal forests of Alaska (Van Cleve 1986, and Johnson 1992) and the negative impacts of fire on many facets of society (Butry 2001) are well documented and present the case for a need to manage for these often mutually exclusive values. In Alaska the large expanse of undeveloped landscape creates a situation where fire managers can manage both for natural fire disturbance regimes and the needs of society, but as the population of Alaska continues to expand - and the wildland-urban interface becomes more widespread and convoluted - so to will the challenge land management agencies face to maintain ecological processes sustained by fire and protect property. As more land in Alaska falls under "full" and "critical" fire management options due to increasing land values the burden on land management agencies to implement prescribed fires as a proxy for natural fires will become greater and a larger public will demand an increased level of assurance that prescribed fires will not generate negative impacts (air pollution, travel restrictions, escaped fires). This situation demands that currently used fire management decision support models improve to meet rising standards.

A number of decision support models are available to land management agencies in Alaska to assist in the evaluation of fuels hazards and to predict expected fire behavior. Evaluating fuel hazards and subsequent expected fire behavior is important on the landscape scale for deciding upon best management strategies and at local scales in determining prescribed fire prescription conditions. Previous research in the boreal forest type (Schimmel 1997) documents (through 15 experimental fires implemented over a seral gradient) that given a detailed assessment of pre-fire fuel conditions, actual fire behavior is well correlated with fire behavior predicted using BehavePlus. However, this is just part of the many facets decision support models. Fuel models provide a rapid method for land managers to characterize fuels and in Alaska the Canadian Forest Fire Danger Rating System (CFFDRS) Fuel Model C-2 is commonly used by land management agencies to assess fuels. Moreover, a new set of Northern Forest Fire Laboratory (NFFL) models (TU01-TU05) recently introduced by J. Scott (unpublished) also have the potential for widespread use in the black spruce boreal forest type.

Research is needed to assess how well predicted fire behavior – using these models – is correlated with predicted fire behavior using pre-fire fuel inputs. Norum (1982) used field assessments to test the original NFFL fuel models for correlation with actual fire conditions and found that adjustments were needed to create models that appropriately modeled actual fire behavior. Assessing fire management decision support models is crucial to understanding how well they predict actual conditions (Morgan 2001, and Scott 2001) and field assessments must be conducted with the CFFDRS C-2 model and the new NFFL models to understand how well they model actual fuel conditions in the boreal black spruce forest type in Alaska. Findings from this research will be used to assess how well these fuel models reflect actual fuel conditions and to modify models to more appropriately reflect natural conditions. Assessing these models will have impacts for boreal forest fire management throughout the state of Alaska and beyond.

General successional trends in Alaska have been well documented using post-fire vegetation-response data from throughout the state and Canada (Bonanza Creek LTER 2000, Boucher 2003). (See Figure on next page).

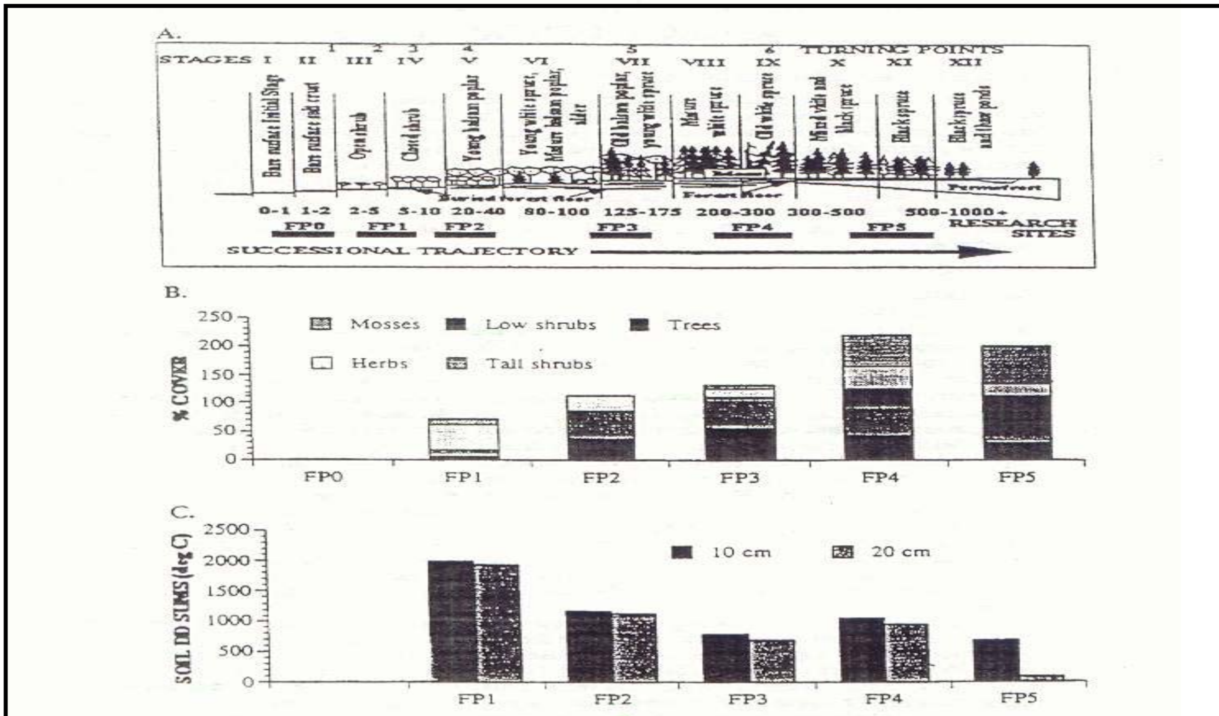


Figure 1.2 Successional sequence on the floodplain of the Tanana River in BCEF, We recognize a series of twelve seres and six turning points in the floodplain successional sequence (A). Turning points represent critical points in ecosystem development where species exert particularly strong control over system physical properties. Changes in percent cover and soil temperature associated with these turning points are shown in (B) and (C) respectively. Soil temperatures are expressed as degree-day sums, which represent the sum of degrees above 0 degrees C over the growing season. Note that plant cover and soil temperature show an inverse relationship as both shading and moss cover increase, culminating in the development of a permanently frozen layer (permafrost).
**Source: Bonanza Creek LTER 2000, p. 1**

Assigning potential flammability measures across this successional gradient would provide an invaluable tool to land management agencies for present and long term fire management planning by allowing more accurate assessments of fuel hazards at the stand and landscape scale using existing GIS fire history map layers. This can be accomplished through amalgamation of post-fire vegetation-response data into a single database to further develop regional successional trajectories of key fuel attributes (ratio of softwood crown cover to hardwood crown cover, total crown cover, forest structure, forest floor moisture and depth) that have the potential to most significantly affect fire behavior. Once key fuel attributes are mapped across a successional gradient for each region expected fire behavior can be predicted across a range of expected weather conditions to develop a seral dependant flammability curve model for boreal forest types in Alaska. These fire behavior predictions can then be assessed across a range of seral stages and fire weather conditions using point verification with fire event data collected from this research. Moreover, relationships established between wildland fire behavior and burn severity from fire event data can be incorporated into the flammability curve model to evaluate potential burn severity across a successional gradient.

## Project Objectives

In general the objectives of this proposed research are to promote understanding of relationships between wildland fire and the black spruce boreal forest environment of Alaska and to provide land management agencies with effective means to manage for natural fire regimes while concurrently protecting property that is vulnerable fire damage. More specifically the objectives of this project are to:

1. Collect a temporal gradient of abiotic and biotic data surrounding fire events (pre-fire stand characteristics, fire weather, fire behavior, post-fire burn severity) for the boreal forest type in Alaska.

2. Apply key fuel attributes primarily responsible for measures of flammability (rate of spread, flame lengths) to amalgamated post-fire vegetation-response data to determine a flammability curve for successional pathways of boreal forest types and test expected flammability against fire event data.

3. Assess correlations between measured fire behavior and burn severity and employ flammability curve to predict potential burn severity impacts over successional pathways.

4. Using fire event data compare predicted fire behavior using CFFDRS C-2 Fuel Model/NFFL Models TU01-TU05 and measured fire weather as Fire Behavior Prediction (FBP) System/BehavePlus (respectively) inputs with predicted fire behavior using actual pre-fire fuel input data and fire weather as FBP System/BehavePlus inputs. Follow comparisons with specific recommendations for modifications to respective fuel models.

5. Create a standard pre-fuels assessment/fire behavior/burn severity form (based on synthesis of extant literature regarding fire behavior in the boreal black spruce fuel type) for use by fire management personnel in the field to collect data that will be pooled to create a comprehensive dataset of estimated conditions surrounding fire events.

## Background

### Ecology

The current structure and composition of the black spruce boreal forests type in Alaska was established 4000 to 6000 years BP and during this time fire presumably maintained the equilibrium of successional gradients found across the present day Alaskan landscape. Black spruce forest types in Alaska are regularly impacted by stand replacing fires approximately every 80 to 90 years. The boreal forest type in Alaska covers the most land area and black spruce is the most common and the most flammable component of the boreal ecosystem. The black spruce forest type is well adapted to promoting and recovering from stand replacing fires. Black spruce (*Picea mariana*) and associated vegetation have fuel properties and structure that are conducive to high intensity fire behavior and a relatively low fire weather threshold for transition from surface fire to crown fire. Vegetation has adapted to fire through resilient properties such as root sprouting, semi-serotinous cones and high seed dispersal rates. Following fire in the black spruce forest type a flush of vegetation regenerates from surviving vegetation parts and is bolstered in future years from seed sources. Initial post fire vegetation fuel loading is generally dominated by deciduous vegetation and following 50-80 years of development is slowly replaced by more flammable species including black spruce in the overstory and feathermoss in the understory. Over the course of succession the forest floor becomes an increasingly dominant component of the biomass.

### Knowledge Improvement

An increasing flammability with increasing stand age (successional trajectory) in assumed by land managers in Alaska but has not been adequately assessed through direct measurement in the state. Research in the drier pine/spruce boreal forests of Sweden by Schimmel (1997) has indicated relationships between predicted fire behavior and seral stage but these relationships in Alaska are not well understood and research elucidating these relationships would be valuable to land management agencies throughout Alaska and parts of Canada. While Schimmel's (1997) research is important in illustrating these trends it lacks sufficient applicability because it was conducted in an ecosystem significantly different than the black spruce forest type and it was assumed that surface-microclimate conditions remain constant over successional gradients and recent research by Theisen (2003) reveals that altered stand conditions has significant influences on the surface micro-climate and can alter predicted fire behavior.

Currently several post-fire vegetation-response projects are ongoing or recently completed (AFS ongoing projects, Bonanza Creek LTER 2000, Boucher 2003). Amalgamation of this data into a comprehensive database potentially supplemented by additional post-fire vegetation monitoring (NPS/FWS permanent plots impacted by fire) would enable the development or modification of successional models to arrive at reliable successional trends following fire in boreal forest types. Development of reliable successional trends linked with flammability characteristics would allow fire managers to predict expected fire behavior in boreal forest types based on stand age and influential successional factors.

Scientific literature directly linking burn severity, fire behavior and pre-fire stand dynamics is limited and includes recent work being conducted by Ottmar (Ongoing) (please see appendix 1) of the Pacific Wildland Fire Sciences Laboratory in Seattle, Washington on forest floor consumption fire events. More work is needed in this area to understand the dynamics of these three tightly related factors through direct measurement. This information will be of crucial value in evaluating other decision support models that are relied upon by forest managers for fire management planning not addressed by this proposal.

The CFFDRS C-2 fuel model used to characterize the black spruce fuel type in Alaska is rigid and does not account for the wide variety of fuel conditions that exists in the black spruce forest type. Research to generate more flexible models has culminated Scott's (unpublished) new NFFL fuel models among others. Current knowledge regarding the applicability of these fuel models is insufficient and point verification with actual fire events would greatly improve the understanding of how well these models function in the black spruce boreal forest type. Additionally the development of a succession-based boreal black spruce forest type flammability curve model will allow land management agencies to capture flammability characteristics of the black spruce forest type over a successional gradient providing an alternative method for assessing fuel hazards.

**Ongoing Research/Linkages**

Ongoing and recently completed research to test decision support models for fire managers has insofar included the evaluation of forest floor components of consumption models and evaluation of the predictive capabilities of the duff moisture elements of the CFFDRS and the NFDRS (e.g. Rorig 2003, Allen proposed research). This proposed research would complement these findings and contribute to a better process for assessing fire hazards and predicted fire behavior in Alaska. Ottmar's (Ongoing) duff consumption work addresses the need to evaluate duff consumption elements of predictive models in light of the black spruce boreal forest type. The unique fuel types and weather conditions of Alaska demand that decision support model parameters be evaluated and tuned specifically to this fuel type as many of the parameters developed for fuel models do not account for variables unique to Alaska (drainage restrictions imposed by permafrost, lack of fuel moisture and relative humidity recover time during the summer months when daylight hours are extended, and fuel moisture properties of feather moss). Significant cost savings can be realized by investing in research that will use existing logistical field arrangements to optimize data collection. This research in combination with Ottmar's (Ongoing) project will provide a more complete picture of the relationships between fuel characteristics, fire behavior and burn severity and will yield results that address gaps in knowledge and provide practical applications for land management agencies in Alaska. Additionally this data has applications for assessing the Alaska black spruce and white spruce fuel type Alaska Photoseries (Ottmar 1998) and other fuel models not addressed by this proposal.

## <u>MATERIALS & METHODS:</u>

Pre-field season methods will be ongoing and include planning logistical arrangements and tuning data collection techniques to the black spruce boreal forest type in Alaska. Logistical planning to practically implement cooperative research efforts (helicopter, fixed-wing aircraft time, research equipment) will continue through discussions between the four participating research institutions [Pacific Wildland Fire Sciences Laboratory (PWFSL), Missoula Fire Sciences Laboratory (MFSL), Colorado State University (CSU) and Yale University (Yale)] and involved land management agencies [Alaska Department of Natural Resources – Division of Forestry (Alaska DNR), Alaska Fire Service (AFS), U.S. Fish and Wildlife Service (USFWS), National Park Service (NPS), and the State of Alaska (the State)]. As time allows, preliminary data sampling in Alaska will be conducted by the CSU/Yale research team to assess heterogeneity of measured biotic parameters and tailor plot design to capture biotic data with an increased degree of confidence. Members of the CSU/Yale research team participating in data collection within active fire boundaries will be required to obtain requisite certifications that include, as a minimum current FFT2 Red Card certification at the arduous level as stated by the National Wildfire Coordinating Group (NWCG) and appropriate bear safety training from one of the collaborating federal agencies and will follow bear safety protocols.

The planned field season for this research will run from mid-May through late August. Data collection will occur during the 2004 field season and the 2005 field season. Three potential fire events (wildland fire, re-burning of unburned islands created by ongoing wildland fires and prescribed fire) will be used to gather data. Dispatch to fire events will follow as outlined in Ottmar (Ongoing).

**Pre/post-fire Vegetation Data**

For fire events location of the plots will be systematic using pre-determined plot spacing distances and approximate orientation of plot location lines. Once plots are established the plot center will be located using GPS and the plot will be marked using steel conduit tagged with plot number. Two photos will be collected at each plot to document fuel conditions: one standard digital photo, and one hemispherical photo to evaluate canopy coverage (e.g. Schimmel 1997). Additional site and plot characteristics will also be recorded including plot specific terrain features (aspect and elevation), historic weather and stand descriptions for each site. Stand age will be determined using by correlating plot GPS points with the Alaska fire history GIS database and cross referenced with tree core samples collected from each site. Stand age will be considered as time since last fire. The Stereo photoseries for quantifying natural fuels, volume II: Black Spruce & white spruce types in Alaska (Ottmar 1998) data will be used as an alternative method to determine additional flammability measures.

Understory vegetation mass per area will be measured using 4, 2 m² sub-plots from which all vegetation less than 1.3 m (4.5 ft) will be collected. Sub-plots will be located at each of the four cardinal directions 6 m beyond the outermost forest floor pin and within each plot two understory sub-plots will be sampled prior to the fire event and two understory sub-plots will be sampled following the fire event. Understory vegetation from each subplot will be divided into appropriate classes (e.g. herbaceous, woody). Additionally, the understory sub-plots will be used to collect 1 and 10-hour course woody debris. If samples are too large for transport they will be weighed onsite and sub-samples will be collected to determine dry weight, which will be correlated with sample weight.

Larger course woody debris (100 and 1000 hour fuels) will be measured using alternate variable line intersect sampling as defined by Kaiser (1983). Two line transects with midpoints at plot center will be located at each plot center. Line endpoints will be marked for re-sampling following fire. This method assesses particle volume that will be converted to a mass per unit area value using known wood density values for black spruce at different stages of decomposition. Decay class will also be assigned for each measured particle. Transects will be re-sampled following fire.

Overstory vegetation will be measured and will be separated into saplings (trees over 1.3 m in height and with a dbh less than 2.54 cm) and trees (individuals over 2.54 cm in dbh). Saplings will be measured using a circular plot design. Trees will be measured through point sampling with a relascope and appropriate BAF. Each tree included will be tagged with a unique number. Species, height, and dbh will be recorded. Mass features (crown mass, total mass) for saplings and trees will be determined using established ratio estimators (Stocks 1980). Plots will be re-sampled following fire events

Fuel moisture samples will be collected immediately before impact by fire (within a safe timeframe) from fuel types measured above (herbaceous fuels, woody understory vegetation separated by evergreen and deciduous, coarse woody debris separated by size class, and coniferous tree foliage).

**Fire Behavior Data**

Upon impact of plots by fire, measurement of fire behavior data will begin. Flame length and rate of spread (ROS) will be the fire behavior variables measured for data analysis. Flame length and ROS, along with other variables such as spotting and torching will be observed and documented by handheld still photography or video recording. This will improve understanding of fire behavior for related studies and assess results collected from actual measurements.

Flame length will be measured by installation of at least three video cameras with wide-angle lenses placed at systematic points along the transect used for forest floor measurements (to insure fire behavior corresponds with data collected for inputs into prediction models). These cameras will be placed in fire and heat proof insulated boxes, similar to the system used by Mangan (1997). Three 8ft. steel poles, one corresponding to each camera, will be set up not more than 10ft away so as not to be obscured by smoke (Mangan 1997). These poles will be marked every foot with metal flags (Rothermel and Rinehart 1983).

ROS will be measured in two ways, as suggested by Rothermel and Rinehart (1983) in Field Procedures for Verification and Adjustment of Fire Behavior Predictions. First, a handheld rangefinder will be used to find a marker distance at the beginning and end of a specified time period. Triangulation will be used to find the distance between the two markers. Second, the fire front will be observed and contour lines drawn on a high-resolution map to correspond with front location at predetermined time intervals. Time will be noted for every line drawn. ROS will be measured several times along the fires path to obtain an average distance and variance over time.

Additionally a standard fire behavior report form will be developed for use in the field by fire management personnel. Data gathered from this form will be used to provide assessments of important fire behavior parameters for wildfires in Alaska and will be useful for further research on broader spatial and temporal scales.

**Post-fire Vegetation-response Data**

Data will be collected from multiple sources throughout Alaska (e.g. Boucher 2003, Bonanza Creek LTER 2000) and organized by region using a database management program (e.g. Microsoft Access). Additionally post-burn severity data obtained from this research will be added to this database as reference to first order fire effects. If time and opportunities are available permanent plots impacted by fire that have not recently been re-sampled will be measured to increase post-fire vegetation-response database.

**Flammability Curve Model Development**

Post-fire vegetation-response data analysis will calculate key fuel attribute measurements that characterize flammability potential of the Alaskan boreal forest type. Once fuel attributes have been calculated the dataset will be subdivided by region and key fuel attributes will be investigated separately over successional trajectories to assess temporal trends. Once trends have been assessed for each region data will be entered into BehavePlus and examined against a range of possible fire weather conditions to model flammability over seral development. Using stand age and pre-fire vegetation data fire event sites will be aligned with the flammability curve model and predicted fire behavior obtained using the flammability curve model as a fuel input will be compared with actual fire behavior to assess the model.

Measured burn severity and fire behavior relationships will be generated using this data and pre-existing available data. This relationship will be applied to the flammability curve model to understand expected burn severity trends throughout the course of successional development.

**NFFL Fuel Models TU01-TU05 & CFFDRS Fuel Model Evaluation**

Measured inputs (wind speed, slope, fuel moisture, etc.) will be entered into BehavePlus and the FBP System and their predictions compared with actual observations and measurements using the noted NFFL and CFFDFS fuel models. Fire event observation forms will be collected from fire management at the end of each season. These will be used to support actual measured fire event data in similar stands. Statistical relationships between predicted and measured flame length and ROS will be made using simple linear regression (Rothermel and Rinehart 1983 and Andrews 1980) and a chi square goodness of fit test. These tests will assess the C-2 (CFFDRS) and Fuel Models TU01-TU05 (NFFL) fuel types as inputs for BehavePlus and the FBP System.

**Project Team**

| Personnel | Responsibility |
|---|---|
| Jennifer Allen, Fire Ecologist – National Park Service. | NPS logistics, project consultation |
| Annie Brown, Graduate Student – Colorado State University. | Study design, data collection, data analysis, publications |
| Ann Camp, Lecturer & Associate Research Scientist – Yale University. | Project coordination, project consultation, oversight for vegetation aspects of this research proposal |
| James Cronan, Graduate Student – Yale University. | Study design, data collection, data analysis, publications |
| Randi Jandt, Fire Ecologist – Bureau of Land Management, Alaska Fire Service. | AFS logistics, project consultation |
| Karen Murphy, Regional Fire Ecologist – U.S. Fish and Wildlife Service. | USFWS logistics, study design, project consultation |
| Philip Omi, Professor and Director of WESTFIRE – Colorado State University. | Project coordination, project consultation, oversight for fire behavior aspects of this research proposal |
| Roger Ottmar, Research Forester – U.S. Forest Service, Fire & Environmental Research Applications Team. | Forest Floor Consumption & Smoke Characterization project contact, PNW logistics, integrated study design advisor |
| Joel Reynolds, Biometrician – U.S. Fish and Wildlife Service. | Project consultation for computer model evaluations, study design and statistical analysis |
| John See, Community Forestry Coordinator – Alaska DNR – Division of Forestry. | Project consultation, computer model applications analysis |

## DELIVERABLES

1. Comprehensive dataset providing directly connected measurements of biotic and abiotic characteristics surrounding fire events including pre-fire stand characteristics, fire weather, fire behavior, and post burn severity will be completed by Fall 2005.

2. Extensive database of cumulative post-fire vegetation-response data for boreal forest types in Alaska will be completed by Fall 2005.

3. Point verified successional gradient flammability curve model that explains general relationships and trends between seral stage and expected fire behavior/burn severity over a range of fire weather conditions will be provided by Spring 2006.

4. Boreal forest type-specific improvements to the CFFDRS Fuel Model C-2 and NFFL Fuel Models TU01-TU05 will be implemented in Spring 2006.

5. Electronic data posting and electronic posting of project summaries in Winter/Spring 2005.

6. Final reports and presentations to interested/participating agencies and research institutions in Spring 2006 regarding flammability curve model and NFFL and CFFDRS fuel model assessments and modifications.

7. Research findings submitted for publication in a refereed journal in Spring 2005 (if applicable) and Spring 2006.

8. A more complete understanding of the processes and relationships that exist between the boreal forests environment of Alaska and wildland fire.

9. Complete records of data associated with each plot will be provided to the appropriate land managers in Spring 2006 to enable them to use these plots for long-term monitoring

## SCIENCE DELIVERY & APPLICATION

This proposed research is a cooperative effort between four research institutions (CSU, MFSL, PWFSL, and Yale) and four land management agencies (Alaska DNR, AFS, NPS and USFWS). Each of the eight participating agencies has vested interest in applying the common results of these two merged projects to the natural resources management community and a concerted effort will be extended to accomplish this. As the study progresses information bulletins and updates will be published to inform relevant land management organizations (Alaska DNR, AFS, NPS, USFWS, and US Forest Service) of meaningful results. Currently maintained participating agency web pages that serve as data access sites such as the Bureau of Land Management – Alaska Fire Service Fire Effects Database (http://fire.ak.blm.gov under "Fire Effects") will serve as locations to post data generated from this research. Project informational summaries such as JFSP progress reports will also be posted on participating agency/institution web pages. Toward the end of the study informational presentations will be made to relevant organizations regarding fuel model assessments and flammability curve model development. Final reports of findings will be disseminated to participating land management agencies and research publications will be prepared and submitted.

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